FA24 Telecom Systems Engineer Course

Practical Exercise 1: Network Cabling

OBJECTIVES

Students should develop an understanding of network cabling design, specifications, installation, and troubleshooting techniques. Students will create and test several cables, which will be employed in future live networks.

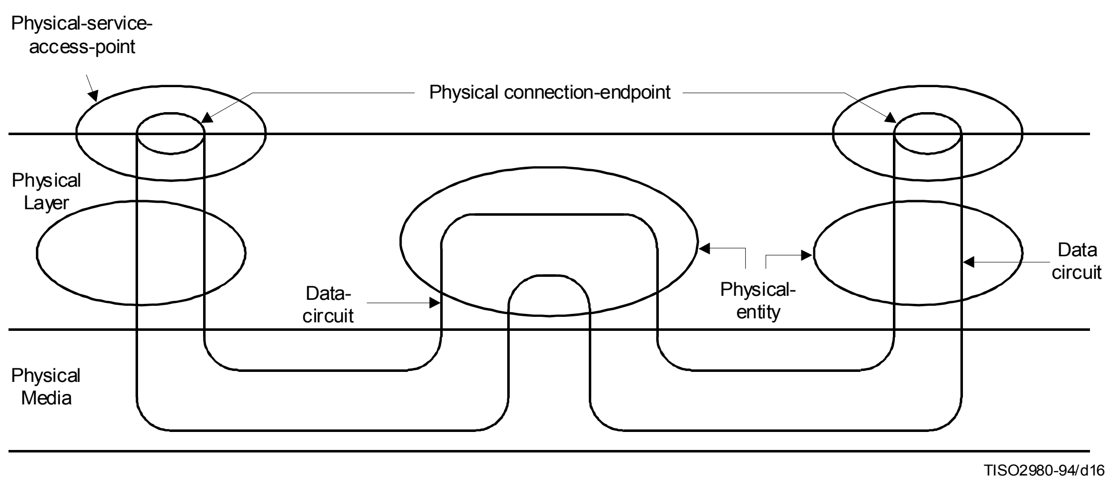
INTRODUCTION

Approximately 50% of networking installation costs will be the cable plant, which should last about 10 years if installed properly. Adherence to a structured cabling standard is critical. Standards bodies such as ANSI, NEC, and UL each have their own wiring standards. The most common wiring standard used for commercial LAN installations is the TIA/EIA-568-A (Commercial Building Telecommunications Cabling Standard). The TIA/EIA-568-A is an open standard that defines the installation and performance characteristics of a universal wiring system. It is used in conjunction with other standards such as EIA/TIA-569 Commercial Building Standards for Telecommunications Pathways and Spaces and TIA/EIA TSB 67 Transmission Performance Specifications for Field Testing of Unshielded Twisted-Pair Cabling Systems.

This lab introduces various cables, connectors and test equipment. The lab will also introduce techniques utilized for fabricating (crimping, soldering and mapping pins) cables and tips on how to troubleshoot defective cables.

NOTE: All Ethernet and TELCO cables that are fabricated in this lab will be used in upcoming Practical Exercises.

Physical Layer vs. The Media:



The OSI Physical Layer provides the mechanical, electrical, functional and procedural means to activate, maintain, and de-activate physical-connections for bit transmission between data-link-entities. A physical-connection may involve intermediate open systems, each relaying bit transmission within the Physical Layer. Physical Layer entities are interconnected by means of a physical medium.

Cable Installation

When installing cable, make sure that adherence to the specifications are maintained. Some of the TIA/EIA-568-A specs are listed below. Note that there are two different pinouts for the termination of CAT 5 cable to an RJ-45 connector. TIA/EIA-568-A is the wiring standard we will use for this lab. It is important to maintain the same wiring scheme throughout or connectivity problems will result.

Typical Workmanship and Installation rules in the Standard:

Document	Rule	Measure	Applicable to:
EIA/TIA-568-A	Terminate w/connecting hardware of same or higher category		Horizontal cables
	Maximum amount of untwist at termination, for 100-ohm cable	13 mm (0.5 in) Cat 5	
	Maximum amount of untwist at termination, for 100-ohm cable	25 mm (1.0 in) Cat 4	
	Maximum pulling tension	110 N (25 lbf)	4-pr
	Minimum bend radius	>4x the cable diameter	4-pr
		>10x the cable diameter	Multipair

Other installation / troubleshooting tips:

--Make sure pins on RJ-45 connector are evenly crimped. Pins that are not fully crimped can cause intermittent failures that are hard to troubleshoot.
--Avoid using two circuits on the same wire, even though you may have spare wire pairs.
--Be sure to handle the cabling with care. Kinks and bends in the wire can cause errors.
--Make sure the same wiring scheme is used throughout.
--Medium to high-speed networks should never use untwisted cabling.
--Disconnect cabling from hub or MAU before testing. Improper readings will result or the hub might crash.
--Make sure to follow the installation guidelines for CAT5 when implementing high-speed networks.

Many network managers are unaware that the data-carrying capacity of the protocol rarely corresponds directly to the bandwidth of the link. (MHz is not the same is Mbps). As an example, several popular protocols are shown in the table below, by their data rate, the bandwidth of the link after encoding and compression, and the grade of link required. The numbers shown are dependent upon the media access implementation (i.e., which encoding scheme is used, whether data is sent in half-or full duplex, and how many pairs are required.)

Protocol	Raw Data Rate	Fundamental Frequency	Cable Test Requirement	Required Cable Grade
10BASE-TX	10 Mbps	10 MHz	10 MHz	Cat 3
802.12 (VG)	100 Mbps	15 MHz	15 MHz	Cat 3
100BASE-TX	100 Mbps	31.25 MHz	80 MHz	Cat 5
FDDI (over copper)	100 Mbps	31.25 MHz	80 MHz	Cat 5
ATM	155 Mbps	77.5 MHz	100 MHz	Cat 5

Category 5 Cable

By far the most common cabling is ordinary telephone wire, but newer networks rely more on standard Category 5 cable. This twisted pair wiring uses 8-pin modular (RJ-45) connectors. Ethernet cables are used more commonly in a 10BasetT or 100baseT network. Communication components will very depending on the systems functionality, thus introducing different wiring schemes that are dependent upon its back-plane connectors. If a system has different manufacturer components, technicians will need to fabricate the appropriate cables for proper physical connectivity. When connecting to different manufactured components, pin-outs will very. Most component operating manuals will list its back-plane connector pin-outs.

Test Specifications for Required tests for TIA/EIA-568-A Certification of Category 5 Cable

--Wire Map: T568A and T568B are the only allowable pinouts

--Length: Max length 100m
--Impedance: 80 - 120 ohms
--Attenuation: 100 MHz => 24 dB or less, varies for other test frequencies
--NEXT: 100 MHz => 32.3 dB or greater, varies for other test frequencies

NOTE: The NEXT measurement must be taken from both ends for accuracy.

Addendum 5 to TIA/EIA-568-A

Addendum 5 to ANSI/TIA/EIA-568-A specifies enhanced category 5 (category 5e) performance requirements. It is strongly recommended that new category 5 cabling installations be specified to satisfy the minimum requirements of this document and it is expected that '568-A-5 will emerge as the new de facto minimum standard for category 5 cabling. '568-A-5 specifies the minimum equal level far-end crosstalk (ELFEXT) loss and return loss requirements necessary to support developments in applications technology and defines the minimum performance that is required for a worst case four-connector channel to support applications that utilize full-duplex transmission schemes (such as Gigabit Ethernet). To ensure additional crosstalk headroom for robust applications support, '568-A-5 also specifies power sum NEXT and ELFEXT loss performance for category 5e cables, links and channels. Addendum 5 to TIA/EIA-568-A is a normative document and, unlike TSB95, it provides mandatory requirements, not recommendations.

Category 6 / Class E

The proposed category 6 / class E standards that are currently under development by TIA and ISO working groups describe a new performance range for unshielded and screened twisted-pair cabling. The charter of the working group developing category 6/class E requirements is to specify the best performance that UTP and ScTP cabling solutions can be designed to deliver. It is anticipated that the category 6/class E requirements will be specified in the frequency band of at least 1-250 MHz and be capable of supporting a positive power sum attenuation to crosstalk ratio (ACR) up to 200 MHz.

For category 6/class E cabling topologies, it has been agreed that the 8-position modular jack interface shall be the mandatory work area interface to be consistent with existing category/class requirements. Category 6/class E specifications will be backward compatible meaning that applications running on lower categories/classes will be supported by the category 6/class E infrastructure. If different category/class components are to be mixed with category 6/class E components, then the combination shall meet the transmission requirements of the lowest performing category/class component.

Optical Fiber

Fiber is composed of an inner core of very pure glass for light to be passed through, and an outer cladding, which reflects light in the core and prevents external light from entering the core. The purity of the glass fiber affects the transmission loss. Current state of the art technology has fiber attenuation down to .2 dB/km.

The three types of fiber currently in use are single mode, graded index, and multimode. Singlemode fiber is narrower in diameter than multimode fiber, and allows only one mode to be passed. Single mode fiber requires a more accurate light source but can be used over greater distances than multimode fiber. Multimode fiber has a larger core, so light beams reflect more inside the cable resulting in greater multi-mode dispersion. The distance an optical signal can be transmitted depends on the type of equipment used, the quality of the fiber, the number of splices, and whether the fiber is single or multimode larger diameter can transport more than one signal at a time. The choice of which fiber to use depends on the application, the transmission distance, the equipment used to transmit and receive the signal, and the data rate.

The technological limits in building accurate and fast light sources and detectors limits the theoretically unlimited bandwidth of fiber optic cable. The function of the light source is to convert an electrical signal to an optical signal. Three wavelength regions are commonly used, 820 nm, 1330 nm, and 1550 nm. There are two popular light sources, the laser diode, and the light emitting diode (LED). The laser provides a more concentrated light beam with a narrower wavelength and can therefore be transmitted greater distances. However, an LED is considerably cheaper to build. Single mode fiber requires the use of a laser light source while multimode fiber can use either.

There are also two common types of light detectors used in fiber optic systems. The PIN derives its name from the PN diode with an intrinsic material (I Layer) in between. The PIN is more economical and uses less expensive circuitry, but is not as light sensitive as the avalanche photo diode (APD). Either can be used as a receiver regardless of the light source. The choice depends on the allowable losses in the system, transmission distance, etc. The advantages of fiber over other forms of cabling include a higher bandwidth, immunity to electromagnetic interference, does not require grounding or conditioning, more secure, lighter in weight, smaller in diameter, has a longer burying life, and lower transmission losses.

Light

Light emitted from fiber optic light sources is different from white light or neon light. Laser light, white light, and neon light have different characteristics. The main differences in these light sources are whether the light is coherent on not coherent, and if the light is chromatic, polychromatic, or monochromatic.

Coherent means that all light given off is in phase, or that the peaks and valleys of the light waves are in the same place. Chromatic deals with the number of frequencies, or colors that the light passes. White light given off by a light bulb is not coherent, and chromatic. Neon light is not coherent, and polychromatic. Laser light is coherent, and monochromatic.

Another difference between these light sources is the way they are projected. White and neon light is scattered in all directions, which diffuses its strength, and creates a softer pool of light. Laser light is concentrated into a single beam so that it can be projected long distances in a straight line. This is why looking at a laser beam can result in eye damage.

The differences between types of light is useful in fiber optics because different single phase light beams can be distinguished from each other allowing more than one beam to be projected at a time. By using monochromatic light, specific wavelengths can be separated and used as separate channels with multimode fiber. Since the light used in fiber optic systems is concentrated and directed, it can be transmitted long distances before attenuation and dispersion (pulse widening) cause the signal to be unreadable.

APPARATUS

--Category 5 cable
--6 Pair cable
--Connectors, DB-9, DB-15, DB-25, DB-37 and RJ-45
--Crimping tools for RJ-45 and DB connectors
--Solder and Soldering Iron
--Multi-Meter w/probes
--Penta-Scanner test set

PROCEDURES

In this Lab you will be required to fabricate and test three types of cables: Ethernet, TELCO and DB –25/37. The Ethernet and TELCO types will use RJ-45 crimp on connectors (*Refer to Appendix A*). The DB-25/DB-37 type will be soldered and crimped according to specific connectors that are needed. You will also be required to troubleshoot defective cables, using different test equipment to isolate and report known faults (*Refer to Appendix B and C*).

Getting Started

During this lab, you will be given the schematics of all cables that you are to fabricate and test. Collect the materials needed from the designated workbench to fabricate each cable and begin.

NOTE: *The key to fabricating any cable is taking your time and mapping out which pins will connect from one end of the cable to the other,* ***<u>no matter the type of cable to be fabricated or tested.</u>***

Build an Ethernet Straight Cable and Ethernet Cross Cable

Ethernet straight cables will be used to connect a workstation's network interface card (NIC) to a hub, which functions as the physical media to the router. Ethernet Cross cables are used to connect hubs to other hubs. In order to fabricate both types of cables you will need the following:

--Cat 5 Cable
--RJ-45 Connector Plugs
--Wire Stripper
--Crimping Tool
--Test Meter (Penta-Scanner)

Ask the lab assistant how many of each cable and the length of each. **[Q1, 2 points]** Use the Penta-Scan device to test each cable and record your results in a table similar to the one below for <u>each</u> cable.

Wire map		Length	NEXT (PENT)	NEXT (INJ)	Attenuation
1	1				
2	2				
3	3				
4	4				
5	5				
6	6				
7	7				
8	8				

NOTE: Refer to Appendix A for standard pinouts.

Build a TELCO Cross Cable

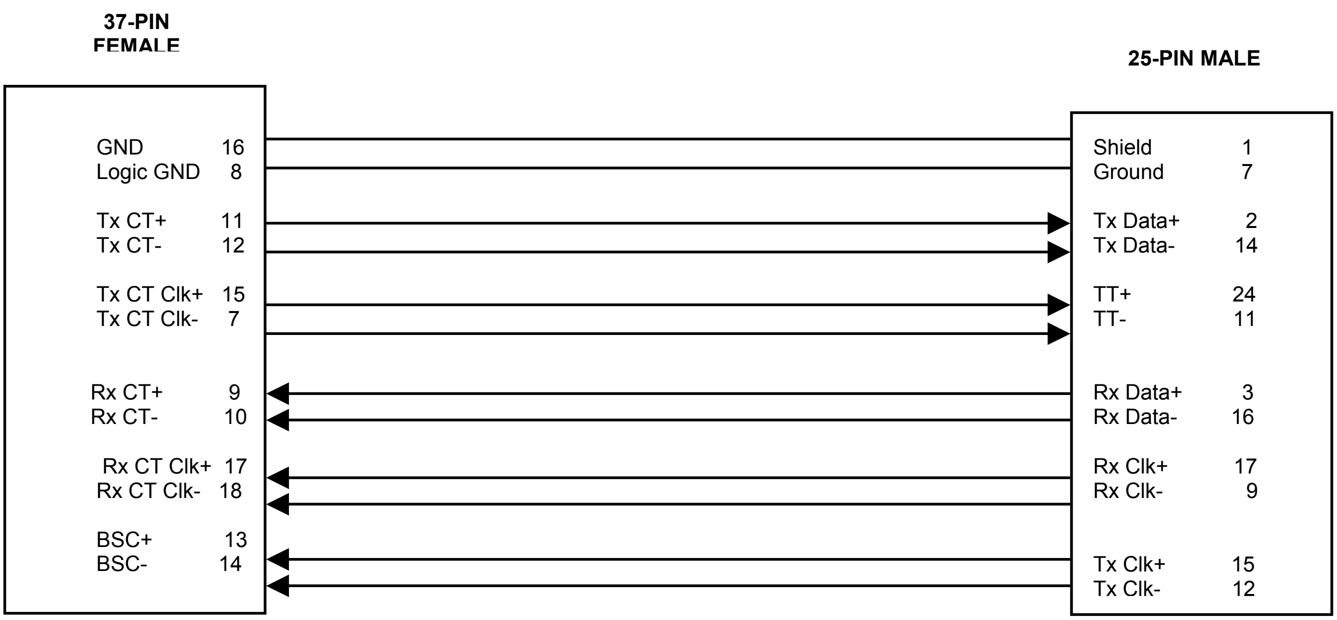
TELCO Cross cables will be used as the physical connectivity between a PBX and a voice-enabled router. In order to fabricate this type of TELCO cable you will need the following:

--Cat 5 Cable
--RJ-45 Connector Plugs
--Wire Stripper
--Crimping Tool
--Test Meter

Ask the lab assistant how many Telco cables and the length of each your group needs to make. **[Q2, 2 points]** Use the Penta-Scan device to test the cable and record your results in a table similar to the one in the previous section.

Build a DTE 37 Female to DCE 25 Male Cable

This cable will be crimped on the 37-pin end and soldered on the 25-pin end for familiarization of both techniques.



As a group, create one DTE 37 female to DCE 25 cable. **[Q3, 2 points]** Use the multimeter to test the cable and record your results.

Troubleshooting Defective Cables

The Instructor will give each student three defective cables, student will be required to troubleshoot each using different test equipment to isolate and report all known faults.

[Q4, 5 points] Given an Ethernet cross cable, find fault(s).

[Q5, 5 points] Given a TELCO cross cable, find fault(s).

[Q6, 5 points] Given a DB-25 (F) Crimped to a DB-25 (M) soldered, find fault(s).

NOTE: Group report for questions 1-6. Submit all other questions as an individual report.

Discussion

[Q7, 4 points] Define each of the following:
--Wire map
--Impedance
--Attenuation
--Near-End Cross talk (Next) Loss.

[Q8, 4 points] When you measure the near end cross talk in a cable do you need to measure from both ends? Explain your answer. Does attenuation also needs to be measured from both ends? Why or why not?

[Q9, 5 points] How would the attenuation (total loss in a cable end to end) in a cable vary with the following parameters/methods (increase, decrease, remain the same): briefly justify your responses.

Attenuation	Increases/decreases	As frequency of the input signal	Increases/decreases/does not change
Attenuation	Increases/decreases	As length of the cable	Increases/decreases/does not change
Attenuation	Increases/decreases	As twisting the cable	Increases/decreases/does not change
Attenuation	Increases/decreases	As diameter of the cable	Increases/decreases/does not change
Attenuation	Increases/decreases	As temperature	Increases/decreases/does not change
Attenuation	Increases/decreases	As # of pairs in the cable	Increases/decreases/does not change
Attenuation	Increases/decreases	As shielding the cables	Increases/decreases/does not change

[Q10, 5 points] Repeat Q7 replacing attenuation with NEXT. Justify your answers.

[Q11, 10 points] What is structured cabling? What are the advantages of structured cabling over unstructured cabling?

[Q12, 5 points] What are the differences between Cat 3 and Cat 5 cables?

[Q13, 3 points] True or False: Using Cat 5 cable in an installation ensures it will be rated for 100 Mbps operation. Explain your answer.

[Q14, 3 points] What precautions should you take when punching down your RJ 45 cable above?

[Q15, 3 points] What is the most common category of UTP in existing installations today and why? What category of cables is favored for new installations and why?

[Q16, 5 points] Explain shielding in Shielded Twisted pair cable?

[Q17, 10 points] What is the index of refraction comparison between air, the core and the cladding of a fiber cable?

REFERENCES

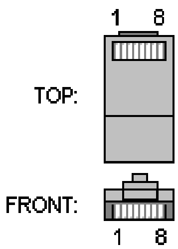
Freed, Les et al. *Get A Grip On Network Cabling*
TruLove, James. *LAN Wiring*
Anixter: http://www.anixter.com
AMP Inc.: http://www.ampincorporated.com
The Simeon Company, De-mystifying category 5, 5e, 6, and 7 Performance Specifications:
http://www.siemon.com/references/tech/demystifying.html

APPENDIX A

PIN-OUT / Color-Code Chart

EIA/TIA 568A/568B and AT&T 258A define the wiring standards and they allow for two different wiring color codes. Recommended use is 568A for Ethernet cabling.

Pinout for T568-A



Pin #	EIA / TIA 568A	Ethernet 10BASE-T	Telco
1	White/Green	X	X
2	Green	X	X
3	White/Orange	X	
4	Blue		X
5	White/Blue		X
6	Orange	X	
7	White/Brown		
8	Brown		

Ethernet Cross-over Cable

Plug A			Plug B		
Pin #	**Signal**	**Conductor Color Code**	**Pin #**	**Signal**	**Conductor Color Code**
1	Tx+	white/green	1	Tx+	white/orange
2	Tx-	green	2	Tx-	orange
3	Rx+	white/orange	3	Rx+	white/green
4	N/U	blue	4	N/U	blue
5	N/U	white/blue	5	N/U	white/blue
6	Rx-	orange	6	Rx-	green
7	N/U	white/brown	7	N/U	white/brown
8	N/U	brown	8	N/U	brown

Telco Cross-over Cable

Plug A			Plug B		
Pin #	**Signal**	**Conductor Color Code**	**Pin #**	**Signal**	**Conductor Color Code**
1	Tx+	white/green	1	Tx+	blue
2	Tx-	green	2	Tx1	white/blue
3	N/U	white/orange	3	N/U	white/orange
4	Rx+	blue	4	Rx+	white/green
5	Rx-	white/blue	5	Rx+	green
6	N/U	orange	6	N/U	orange
7	N/U	white/brown	7	N/U	white/brown
8	N/U	brown	8	N/U	brown

APPENDIX B

Instructions for using a PENTA-SCANNER

Step 1 – Before you can effectively use the Penta-Scanner it must be first calibrated. Do this by connecting the purple calibration from the Scanner to the Injector.

Step 2 – Turn power switch to On. Penta-Scanner will read READY on the LED screen.

Step 3 – Press the EXTENDED FUNCTIONS button. Using the up and down arrow buttons cursor down to #3 Calibrate, If you have done this correctly the Calibrate will be highlighted, press the F1 button which acts as the enter key. The Penta-Scanner will perform a calibration function, which will take about a minute. If LED reads READY, proceed to step 4. If it reads FAIL inform the instructor.

Step 4 – Disconnect the calibration cable and connect the cable you want to test.

Step 5 – Press the AUTO-TEST button. This will take a few minutes because it will be executing various tests for you.

Step 6 – You can view the AutoTest results by pressing Tests (F4) from the AutoTest results screen. Pressing the Up and Down arrows will take you guide you to a list to choose from. Selections are Wire Map, Length, NEXT (Near End Cross Talk), Attenuation, and Impedance.

Step 7 – Pressing the ESCAPE button takes you out of active screen. A message will be displayed on the LED screen “Do you want to save your results”, select NO. The PentaScanner now returns to the ready state to test another cable.

APPENDIX C

Instructions for using a Multi-Meter

Step 1 – Turn dial selector switch to the Continuity with sound setting.

Step 2 – Connect the Red and Black probes in the corresponding plugs on the Multi-Meter.

Step 3 – Touch the two probes together, metal tip to metal tip, if you here a beep sound the continuity selector position is working properly.

Step 4 – Testing a cable for continuity is accomplished by touching PIN x on one end of your connector to the other corresponding pin on the other connector. This is the most effective way of testing a fabricated (DB to DB) cable that can be accomplished because the cables are Non-Standard.